Genetic Algorithm Optimization of Inlet Design for a Hypersonic Jet Engine with Mode Transition

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What is a Genetic Algorithm?

It's a relatively new optimization technique based on biological evolution, and can be adapted for many disciplines of study. In this case, a genetic algorithm is used to find the best design for an aircraft inlet.

Makeup of a Genetic Algorithm

Alleles	The values an individual has for the design variables that the algorithm considers
Chromosome	The genetic makeup of an individual: a list of alleles
Population	A group of chromosomes that compete for survival
Crossover	
Mutation	

How Does a Genetic Algorithm Work?

Thousands of individuals are created over tens of generations. Each individual represents one combination of parameters, one chromosome, for a design task such as this hypersonic inlet.

An objective function evaluates the performance of a chromosome and assigns a fitness value to that chromosome based upon how well it performs.

Roulette Wheel selection chooses parent chromosomes based upon their fitness. The better fit individuals are more likely to pass their design traits on to the next generation. This is analogous to a roulette wheel, where a ball drops onto the wheel at random and is more likely to stop on a larger portion of the wheel.

These parent chromosomes create offspring via crossover. Random offspring are also chosen for mutation, which ensures that the variety of parameter values considered is not limited to those of the initial population. Crossover and mutation occur with specified probabilities. When neither occurs, the parents are simply copied into the next generation.

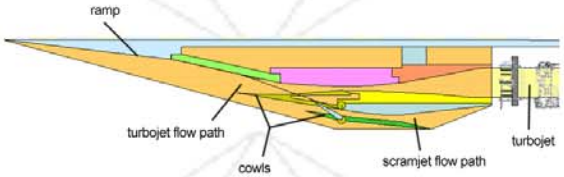
Advantages of Genetic Algorithms

- can search the whole design space and not just "hill-climb"
- can explore parts of the design space far from existing designs
- can consider many design variables and objectives at once
- Knowledge of what makes a "good" design isn't required.
- adaptable to diverse tasks and multidisciplinary optimization
- ideal for parallel computing, drastically increasing efficiency

What is the inlet we're optimizing?

A hypersonic jet is one that travels significantly above the speed of sound, traditionally Mach 5 and above. At these speeds, the stagnation temperature of the air is too hot for a turbojet engine to handle, so a ramjet--or for even higher speeds, a scramjet--must be used instead. Since ramjets and scramjets don't have meltable turbine or compressor machinery, they can stand the high speeds, but they're also dependent on the high speeds to compress the air without the help of compressor blades. That means the vehicle must have both types of engines (or else rocket propellant) to reach hypersonic speeds: a turbojet for subsonic and slightly supersonic speeds, and a ramjet or scramjet for higher speeds.

The inlet optimized here has a turbojet and a scramjet, with cowl flaps to open and close the different flow paths as they're needed. The algorithm will optimize the turbojet flow path.



What about the inlet are we optimizing?

Total pressure recovery. Total pressure, or stagnation pressure, reflects how much work can be extracted from the fluid, so a loss in total pressure indicates an increase in entropy and a loss of ability to do work. Total pressure recovery is a measure of the change in total pressure from one end of the inlet to the other, so it represents of the efficiency of the inlet.

What parts of the design will we change to optimize total pressure recovery?

One of the genetic algorithms will optimize the inlet's bleed schedule, which states where and at what rate air flows out through holes in the inlet walls in order to minimize flow separation.

The other algorithm will optimize the geometry of the inlet walls, again with the intention of preventing flow separation and thus minimizing shock-induced losses in total pressure.

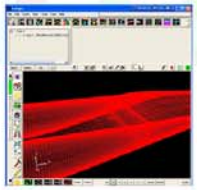
What tools are we using?

Force

a Fortran editor and compiler

EnSight

a visualization tool that takes a grid file and a result file and plots, for example, the pressure or density of flow along the inlet

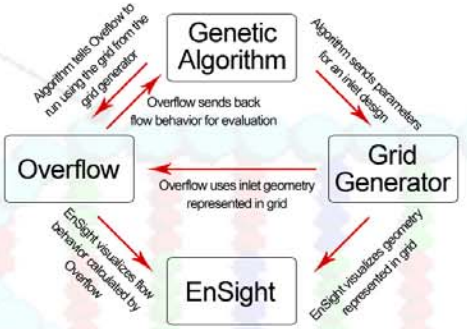


Columbia

a NAS supercomputer where the algorithms will run and Overflow will do its calculations. Columbia's thousands of processors are necessary for calculations of this magnitude to finish within a reasonable amount of time.

Overflow

a Computational Fluid Dynamics (CFD) tool that calculates flow behavior and outputs result files that can be plotted in EnSight. The plot here shows color-coded Mach numbers through a baseline inlet design. Overflow has evolved over decades in response to diverse problems and experimental data.



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